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Economies Associated with Size, Fresno County Cotton Farms

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ECONOMIES ASSOCIATED WITH SIZE, FRESNO COUNTY COTTON FARMS

by

Charles V. Moore[1]

INTRODUCTION

This report is concerned with cost economies associated with farm size for farms producing field crops for sale in Fresno County, California.

Farmers can use the results reported here in making long-term plans in regard to the use of machinery, labor, and land. Policymakers should find the results helpful in making decisions and estimating the effect of their decisions that relate to farm size.

OBJECTIVES OF THE STUDY

The primary purpose of this study was to estimate costs as related to farm size for two general soil types and associated adapted crops in Fresno County: (1) light sandy soils and the crops adapted to it (i.e., cotton, alfalfa hay, grain sorghum, dry beans, and barley), and (2) heavy clay and clay loam soils and the adapted crops (i.e., cotton, alfalfa seed, safflower, sugar beets, grain sorghum, and barley). Three subobjectives were also explored: (1) the variability of the index of output when gross income is used as a measure of output in the multiple product firm, (2) the least-cost irrigation distribution system under different price levels for labor, capital, and water, and (3) the least-cost machinery combination for each level of output in the short run.

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[1] Agricultural Economist, Economic Research Service, Farm Production Economics Division, U.S. Department of Agriculture, Davis, California.

THE STUDY AREA

The cotton-producing area of Fresno County is centered in the western half of the county. This region comprises an area approximately 50 miles long and 40 miles wide. The land slopes gently to the middle of this area and drains into the Fresno Slough. The climate in Fresno County is semi-arid, characterized by hot days and warm nights in summer and a low annual rainfall (10-14 inches on the average). The winters are relatively mild with a frost-free growing season of greater than 275 days that allows for tillage and seedbed preparation throughout the year.

Soils

The two major soil texture types of the study area are separated by the Fresno Slough; to the west of the Slough lies the medium- to heavy-textured soils of the recent alluvial fans. The major soil series of this soil type is Panoche.1/ Light sandy soils characterize the area east of the Fresno Slough.2/ This area contains large areas of lands showing high concentration of alkali and much of it has been reclaimed only in recent years.

The sandy soils are generally better suited to the production of alfalfa hay than the heavy soils. The recent reclamation of the sandy soil creates a management problem which requires constant supervision to maintain productivity. This requires "ripping" with subsoilers instead of the conventional moldboard plow, reapplication of gypsum, and additional irrigation water for leaching to keep the alkali below the root zone. Alkaline sensitive crops are not adapted to this soil since only the upper layer of soil has been reclaimed.

The heavy soils west of the Slough have high productivity indices3/ and a wider range of crops are adaptable. As compared with the sandy soils, these fine-textured soils with inherently high water-holding capacities are more efficient in their use of irrigation water.

1/ U.S. Department of Agriculture, Soil Survey, Mendota Area, California, Soil Conservation Service, 1956.

2/ This area is presently being mapped and classified, and no productivity indices are available.

3/ U.S. Department of Agriculture, loc. cit., based on Storie Index.

Water Supply

Three distinct water supply conditions characterize the study area (see Figure 1). The light soil area east of the Fresno Slough has relatively shallow pump lifts, averaging less than 100 feet. Gallons per minute discharge of the pumps average about 850 to 900 (about two cubic feet per second) and most farms have more than sufficient well capacity to irrigate all summer crops.

A relatively small area in close proximity to the Fresno Slough is serviced by irrigation districts, with canal water being almost the entire source. This area is not considered in this report; only farms under 100 percent pump irrigation were studied.

Deep well turbine pumps driven by large electrical motors characterize the heavy soil area. Depending upon the elevation, total lifts may range from 400 to 1,000 feet. The large motors used to drive these pumps range from 100 to 300 horsepower, depending upon the pumping lift. Farm operators try to maintain the discharge of these pumps near 1,350 gallons per minute. Due to the high cost of a pump of this capacity, the typical situation is one pump per section of land,[1/] or 640 acres, and these pumps are run almost continuously. A pump yield of 1,350 gallons per minute provides sufficient water to irrigate about 180 acres of summer crops on a 14-day irrigation cycle. This provides water for the existing cotton allotments plus some additional summer irrigated crops.

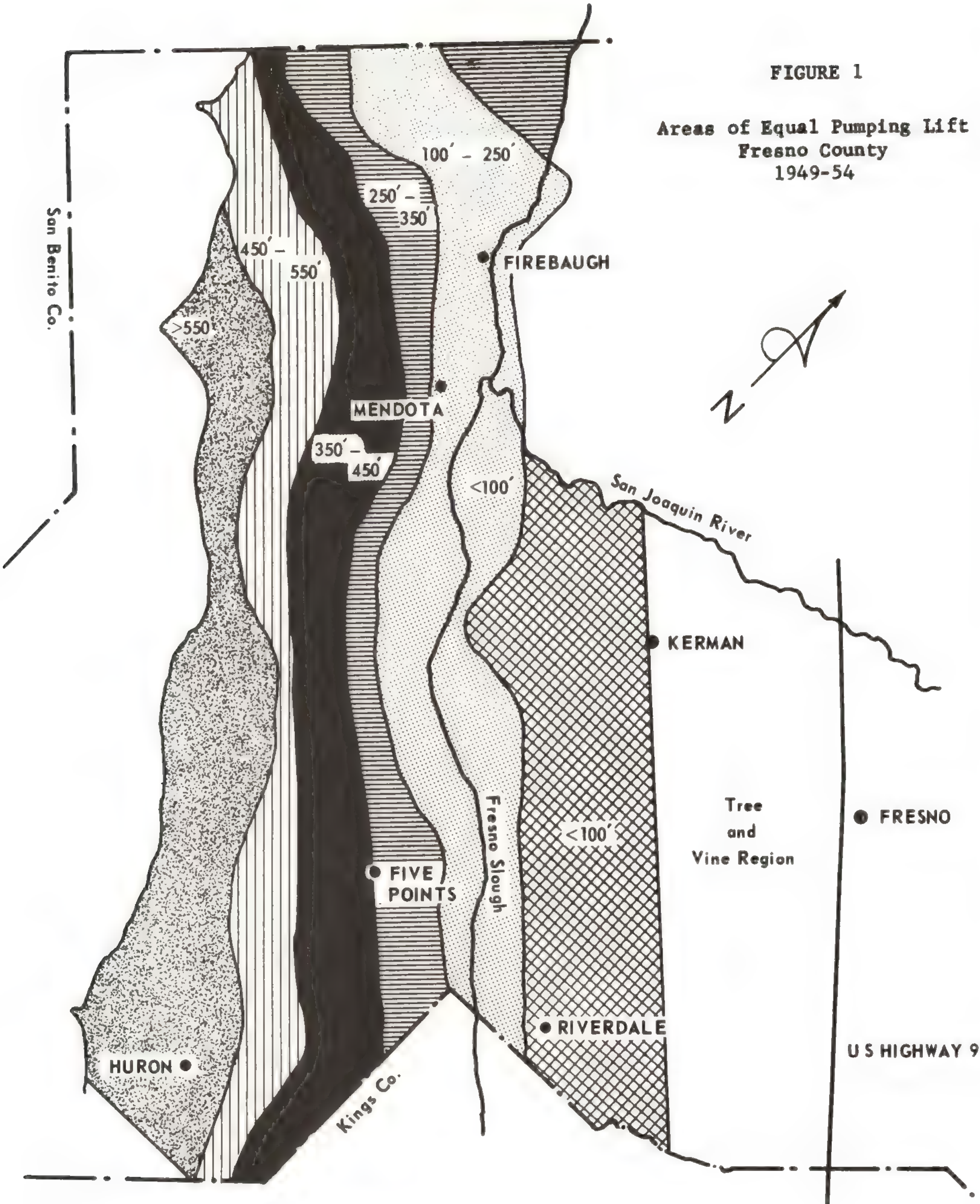
CHANGES IN FARM SIZE

Size of farms in Fresno County has undergone a great change in the last 15 years. Consolidation of units and development of large blocks of land into farms have both contributed to this change. The U.S. Census of Agriculture, which is taken every five years, indicates that the greatest absolute and relative increase in numbers of farms has occurred in the largest size groups. In 1945, there were 266 farms of 1,000 acres or larger (see Table 1). For this same size group in 1959, the most recent census for which data are now available, this number has increased to 345 or about 30 percent increase. Also in 1959, there were 200 farms in excess of 2,000 acres.

[1/] Moore, Charles V., and Trimble R. Hedges, Some Characteristics of Farm Irrigation Water Supplies in the San Joaquin Valley, Berkeley: University of California, Agricultural Experiment Station, Giannini Foundation Research Report No. 258, September 1962, 42 pp.

FIGURE 1

Areas of Equal Pumping Lift
Fresno County
1949-54



Mean Pump lift 1949 – 1954

Source: Moore, C. V. and T. R. Hedges
Some Characteristics of Farm Irrigation Water Supplies, San Joaquin Valley
Op. Cit.

Note: Ground water overdrafts in the western parts of the study have increased pump lifts since this data was collected.

TABLE 1

Number of Farms by Acres of Land, Fresno County, California

Acres of cropland	Number of farms				Percentage distribution				Percentage change in number of farms from 1945		
	1945	1950	1954	1959	1945	1950	1954	1959	1950	1954	1959
	number				percent						
Less than 50	6,142	6,990	6,505	5,134	67.2	69.9	66.5	61.6	+14	+ 6	-17
50 - 69	725	802	761	691	7.9	8.0	7.8	8.3	+11	+ 5	- 5
70 - 99	729	728	730	685	8.0	7.2	7.5	8.2	- 0.1	+ 0.1	- 6
100 - 139	383	290	438	429	4.2	2.9	4.5	5.1	-24	+14	+12
140 - 179	303	271	278	288	3.3	2.7	2.8	3.4	-11	- 8	- 5
180 - 219	115	116	159	150	1.2	1.1	1.6	1.9	+ 1	+38	+30
220 - 259	93	90	110	119	1.0	.9	1.1	1.4	- 3	+18	+28
260 - 499	233	269	281	292	2.5	2.6	2.9	3.5	+15	+21	+25
500 - 999	156	193	193	212	1.7	1.9	2.0	2.5	+24	+24	+36
More than 1,000	266	288	321	345	3.0	2.8	3.3	4.1	+ 8	+21	+30
TOTAL	9,145	10,037	9,776	8,345[a]	100.0	100.0	100.0	100.0	--	--	--

[a] Part of the change between 1954 and 1959 is due to the redefinition of what is a farm, especially in the smallest size group.

Source: U.S. Department of Commerce, Census of Agriculture.

Type of Farming

The study area for this report is defined as that pump irrigated area of Fresno County west of the fruit- and vine-growing districts where open crop land predominates (see Figure 1). Therefore, the primary interest of this study was in field crops.

Cotton is grown on more farms and contributes more to the total value of production than any other single crop. It is estimated that 201,829 acres of cotton were grown on 2,286 farms in Fresno County (see Table 2[1]). Barley had a greater total acreage but was grown on only 423 farms.

Eight crops were considered in this study -- cotton, alfalfa hay and seed, sugar beets, barley, grain sorghum, safflower, and dry beans. These crops produced almost 92 percent of the gross income derived from field and seed crops in Fresno County. The contribution of each of these crops to the total gross income is shown in Table 3.

THEORETICAL FRAMEWORK FOR MEASURING ECONOMIES OF FARM SIZE[2]

In the short run, one or more inputs in the production process of a farm plant or firm are assumed to be fixed. Changes in output of this theoretical firm can be made by changing the proportion of variable inputs to the fixed plant. A trace or curve which plots the average total cost per unit of output, as output is varied, is the short-run average cost curve (SRAC) for this plant.

Expanding the fixed resources of a firm provides a new "fixed plant" for which a short-run average cost curve can be derived. By defining a sufficient number of "fixed plants" and their associated SRAC curves, the minimum cost point and combination of fixed and variable resources for any output included in the analysis can be found.

1/ U.S. Department of Commerce, 1959 Census of Agriculture.

2/ Thorough treatments of the measuring of the economies associated with size can be found many places in the literature. For example, see Viner, Jacob, "Cost Curves and Supply Curves," Zeitshrift fur Nationalo Konomic, Vol. 3 (1931), pp. 23-46. Reprinted, Readings in Price Theory, London, George Allen and Unwin, Ltd., 1956. Also, Heady, E.O., et al., Resource Productivity Returns to Scale and Farm Size, Ames: Iowa State University Press, 1956.

TABLE 2

Crop Acreage, Fresno County, California

Crop	Number of farms	Acres
Cotton	2,286	201,829
Alfalfa hay	1,224	93,290
Alfalfa seed	99	50,128
Sugar beets	87	8,814
Barley	423	207,406
Grain sorghum	194	9,354

Source: U.S. Department of Commerce, 1959 Census of Agriculture.

TABLE 3

Value of Production, Field Crops, Fresno County, California, 1962

Crop	Income	Percent
	dollars	
Cotton	92,273,990	53.7
Barley	22,917,410	13.4
Alfalfa hay	22,727,250	13.2
Alfalfa seed	7,024,630	4.1
Safflower	6,887,500	4.0
Grain sorghum	2,132,000	1.2
Sugar beets	1,951,500	1.1
Dry beans	1,201,500	.6
Other	15,010,810	8.7
TOTAL	172,126,590	100.0

Source: Agricultural Commissioner's Report, Fresno County, 1962.

An envelope curve formed as a tangency to these short-run curves is defined as the cost planning curve. Certain institutional constraints (cotton allotments) are retained in order that some indication can be made of the restrictions on expansion of output faced by producers. If this constraint were not included in the analysis, the curves presented would be considered as conventional long-run cost curves.

In this report, the year-round or permanent labor force is assumed to be the "fixed plant." The variable resources are the machinery and land (owned, rented, or hired) which could be utilized by this labor force. Thus, in the hypothetical illustration in Figure 2, $SRAC_1$ would represent the average total cost per unit of output for a range of output assuming a fixed labor force (here unspecified) while land, machinery, and other inputs are varied. $SRAC_2$ would represent a larger fixed labor force while varying the other resources.

Economies associated with size arise from two sources -- technical and pecuniary. Pecuniary economies are the result of decreases in average total cost as size of plant is increased due to reduced acquisition costs of inputs or increased selling prices. Faris and Armstrong have reported some of these economies for a study in Kern County. A detailed discussion of the sources and effects of these economies is presented in their report.1/ Pecuniary economies are not analyzed in this report, so all cost reductions are due to technical economies.

Technical economies usually are associated with more adequate utilization of the productive capacity of the resources. Technical economies also arise from the ability of larger firms to utilize larger, more efficient specialized machines in their production processes. In this study, yields and production techniques are based upon a high level of managerial ability and technology. Therefore, the technical economies shown later in this report are ones that are considered to be attainable and not average results.

Multiple Product Firms

None of the methods thus far utilized has been found to be completely satisfactory for measuring output in a multiple product firm. This report,

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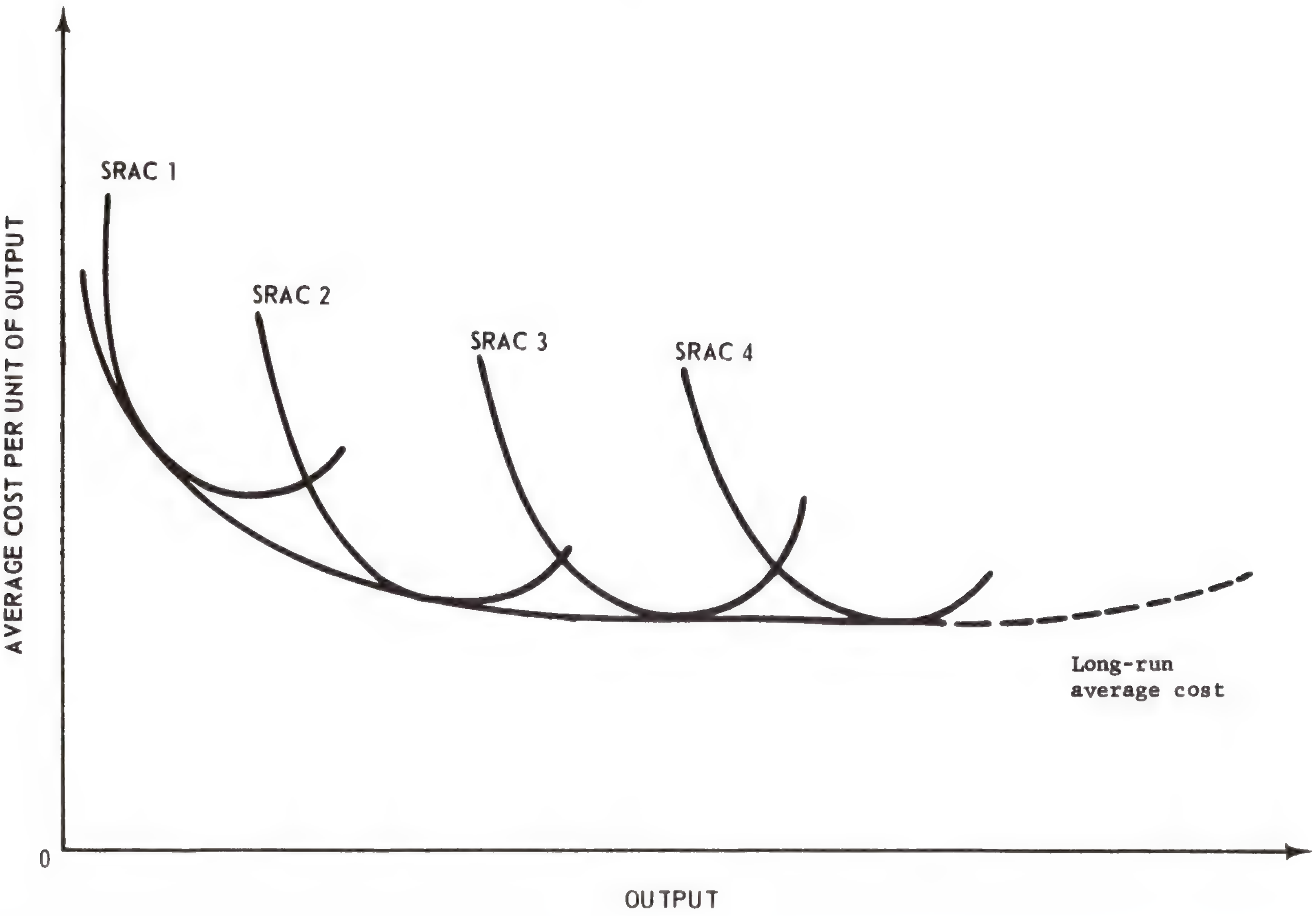
1/ Faris, J. Edwin, and David L. Armstrong, Economies Associated with Size, Kern County Cash-Crop Farms, Berkeley: University of California, California Agricultural Experiment Station, Giannini Foundation Research Report No. 269, December 1963, 121 pp.

FIGURE 2

Hypothetical Short-Run and Long-Run
Average Cost Curves



following Dean and Carter,[1] will use gross revenue to measure output. This approach has been criticized because it uses product prices as weights in measuring output (sum of Price x Quantities = Gross Farm Revenue). The primary criticism is that many product prices are highly variable and these prices do not always vary in the same direction to make a reliable measure of output. Therefore, the slope and position of the cost curves measured in this manner may shift from year to year. Further, the cost curves, when presented graphically, indicate a fixed point as the least-cost combination when in fact this point may fluctuate due to changes in the product prices used as weights. This, in turn, may cause these curves to be misinterpreted. Yield, the second element in the total revenue equation, also can vary. Estimates will be made of the variability of gross revenue resulting from variability in price and yield for both the planning curve and the short-run cost curves. The range within which the cost curves might fluctuate will be plotted around the expected cost curves. This will not eliminate the objection to the fluctuation of the cost curves; however, it will aid in their proper interpretation.

Price, Yield, and Income Variability

Tintner's variate difference method[2] is used to measure variability in this study. Variability as used in this and other studies[3] arises from the random (as opposed to predictable) variations in prices, yields, and therefore, incomes. That is, the objective is to separate out the random component of these variables from the predictable component. This random component or variance will be used to determine the total variability of gross income for each cropping program calculated.

Gross income variability for a particular crop on a per acre basis results from the interaction of both price and yield variability. Total income variability for a cropping program, including two or more crops, depends upon the correlation between the income variances and the proportion of each crop in the program. The principles of determining total variance of a cropping program are explained by Heady.[1/]

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[1] Dean, Gerald W., and Harold O. Carter, Cost-Size Relationships for Cash-Crop Farms in Yolo County, California, Berkeley: University of California, California Agricultural Experiment Station, Giannini Foundation Mimeo. Report No. 238, December 1960, 63 pp.

[2] Tintner, Gerhard, The Variate Difference Method, Bloomington: Principia Press, Cowles Commission Monograph, No. 5, 1940.

[3] Carter, H.O., and G.W. Dean, "Income, Price, and Yield Variability for Principal California Crops and Cropping Systems," Hilgardia, Vol. 30, No. 6, October 1960, pp. 175-218.

An understanding of the variance associated with a crop or cropping system will aid operators in assessing the risks[2/] associated with an undertaking. For example, a beginning operator who has assumed a large mortgage will want to know both the expected average income and the variability of this income. If this beginning operator decides to "play it safe," he will wish to choose a cropping plan that contains a small variance and perhaps a lower average income to guard against bankruptcy as opposed to a crop plan with a high income but also a high variability.

The square root of the total variance (standard deviation) for the gross income of each cropping plan calculated was determined. As indicated in the theoretical section, total costs for each short-run plant size was divided by gross income to obtain the average cost per unit of output (in this case, dollar) of gross income. To indicate the range within which this value would be expected to fluctuate,[3/] total costs were divided by a value plus and minus one standard deviation away from the expected gross income. When plotted on a chart, these ratios form a band around the expected short-run curves.[4/]

No attempt was made in this study to select cropping programs with a predetermined total variance level or to minimize the total variance. Procedures for minimizing absolute variances of income from a cropping program are set forth by Carter and Dean[5/] and by Heady.[6/]

[1/] Heady, E.O., Economies of Agricultural Production and Resource Use, New York: Prentice-Hall, Inc., 1952, pp. 510-516.

[2/] Knight, F.H., Risk, Uncertainty, and Profit, Boston: Houghton Miflin, 1921. Knight defines risk as a situation where the probability of given outcomes is known and could be insured against. Uncertainty is defined as a situation in which the probability is unknown and cannot be determined.

[3/] Assuming a normal distribution, two-thirds of the observations would be expected to be found within plus or minus one standard deviation from the mean.

[4/] Fluctuations in input prices, an additional source of variability, are not taken into account in this part of the study. Total costs vary not only due to changes in the prices of inputs, but also due to weather and insects. We have assumed that input costs are constant and the confidence interval is determined by dividing a constant by a variable. This understates the range of fluctuations of the A.T.C. curve.

[5/] Carter and Dean, Income, Price, and Yield Variability ...., p. 191.

[6/] Heady, op. cit., p. 514.

Prices and Yields Used

Historical data were not available on prices and yields for geographic units smaller than a county basis. Because of this, the State prices and county yield data were used in estimating income variability.

Expected prices used in this analysis were those projected to 1967 by the U.S. Department of Agriculture and adjusted to meet local average grades and transfer costs from pricing points. Yields used in the linear programming analysis are above county averages to reflect a high level of management. (See Appendix Tables 1 and 2 for prices and yields used in this analysis.)

Assumptions and Definitions Used in the Empirical Analysis

Gross income is gross farm sales plus the market value of those usual farm products used in the household whose cost of production is included in farm expenses.

Regular labor is the labor which is committed to the farm for the entire production season. The maximum allowable number of man-hours available per man-year of regular labor is 2,500. No more than 300 hours per man is considered to be available in any one month. The maximum number of days available was reduced to reflect days lost in the field due to winter rainfall which prevents machines from operating. The total annual labor supply was reduced further by a constant ten percent to allow for supervision and management, as discussed below.

Supervisory labor and management were assumed to account for ten percent of the total available labor, based on a small interview sample. This means that on a farm with a regular labor supply of four men, 40 percent of the manager's time would be spent in supervising labor and other management functions. This time is not available for direct field labor.

Seasonal labor is allowed in the analysis on an hourly basis up to a maximum of 50 percent of the regular labor force. This seasonal labor is considered to be equal in skills to those of the regular labor force.

Land tenure (in this study) is concerned with the long-run planting situation for an operator who is starting a new farm business. It assumes, that in the long run, rental payments will approach or equal ownership costs. Therefore, for the sake of simplicity, this study assumes that land is under full ownership.

LEAST-COST IRRIGATION DISTRIBUTION SYSTEMS

One of the objectives of this study was to select a least-cost distribution system for irrigation water. This part of the study was separated from the machinery cost phase to better isolate and measure the factors involved. By budgeting ten different distribution systems and fitting a statistical production function to the results, it was possible to estimate the substitutability of capital, labor, and water for each other. Knowing this substitution rate, it was possible to determine the optimum system under any combination of prices or costs of the three factors. The method used here is more general than required for the two areas under study, but it does allow specification of the optimum system to be included in the farm model in the following sections.

There are a large number of methods available to the operator to transport water to the crops to be irrigated. The simplest method is to use unlined earthen ditches to carry water to a head ditch running along the upper edge of the field. Water is then siphoned out of this head ditch into the furrows (in the case of row crops) or into the checks (in the case of solid-planted crops). Open ditches require the least capital investment; however, this system requires a large amount of labor to set, move, and supervise the siphon tubes and for weed control along the ditch banks. Water losses are high under a simple system such as this in that seepage and evaporative losses occur in the ditch. Large tail water losses may occur at the lower end of the field. These latter losses may be recouped by use of a sump pump to pick up excess water and pump it back into a head ditch.

Another method of transporting and distributing water is to use underground concrete pipelines to replace all, or part, of the unlined ditches. The investment per acre is much higher when concrete pipeline is used; however, the need for weed control and ditch losses is eliminated and labor requirements for setting and moving siphons are reduced.

Deep percolation and tail water losses can be reduced by shortening the length of field or run. Shortening the length of run requires additional ditches or pipeline as well as increased labor to set and move siphons.

Return water systems operate independently of the method of conveyance. Therefore, each method will be analyzed with and without a sump pump and return lines.

No two farm distribution systems are exactly alike. This is due to pump location on the farm, soil type, cropping program, physical obstacles such as slope of the land, and field shape. It would not be expected, then, that the specifications and investments used in this analysis would fit exactly any one particular farm. However, the results should indicate to farm operators the general type of distribution system they should consider in future planning.

Procedures

Data for this analysis were not readily available. In a practical sense, it would have been difficult to obtain the necessary data on labor requirements, capital investments, and irrigation efficiencies from a survey of farmers or controlled experiments on field plots. It was decided, therefore, to enlist the cooperation of four engineers experienced in the design and construction of distribution structures.[1] The engineers provided labor requirements, application efficiencies, and physical specifications on all the above items for two soils -- a deep sandy loam and a silty clay -- under both border (checks) and furrow irrigation. A further assumption was that management would be of sufficient quality that yields would not change under the different methods.

Data developed by the panel of engineers were used to synthesize ten different water distribution systems composed of combinations of concrete pipeline, open ditches, lengths of run, and return water systems.

A typical cropping system for each of the soils was selected and total water use, total labor, and average annual capital requirements for the various distribution systems were determined for four farm sizes.

A regression equation was fitted to these data to estimate the overall substitution rates among the three inputs (capital, labor, and water).[2] It was

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[1] Larry Booher and Clyde Houston of the University of California, Davis, and Sarkis Sarabian and Art Dunkel, Soil Conservation Service, U.S. Department of Agriculture, Fresno, California.

[2] A production function of the form of:

$$Q_o = b_o L^{b_1} C^{b_2} W^{b_3} \qquad (1)$$

was assumed, where L = Labor, C = Capital, and W = Water. This relation implies an isoquant for an unspecified output of the form of:

Continued on next page --

assumed that as the price of one of the three inputs became higher relative to the other two inputs, a prudent operator would attempt to use a system that conserved the expensive input. For example, if an operator were in an area of rapidly increasing water costs due to overdraft conditions and the cost of capital (interest rate) and wages remained relatively constant, he could minimize costs by utilizing more water-conserving structures and practices. The higher the price of water in relation to the cost of the other two inputs, the more water-conserving structures he could afford to install. On the other hand, if labor became relatively more expensive, a least-cost distribution system would include more labor-saving devices.

The ten water distribution systems (see Table 4) used in this study do not include all possible alternatives. Additional combinations can be made which include gated pipe, open concrete lined ditches, and a variety of sprinkler systems. An attempt was made to obtain labor data and irrigation efficiency estimates for some of the above surface systems; however, these data were not available. Sprinkler systems were not considered in this study.

2/ Continued from previous page --

(2) $$\text{Log } W = \frac{\log b_o - \log Q_o}{-b_3} - \frac{b_1}{b_3} \log L - \frac{b_2}{b_3} \log C$$

Using a Lagrangian multiplier, the cost function takes the form of:

(3) $$G = P_1 L + P_c C + P_w W - \lambda \left[k + b_1' \log L + b_2' \log C - \log W \right]$$

Solution of equations obtained from necessary conditions for cost minimization when λ is the Lagrangian multiplier and b_1' and b_2' are the coefficients estimated in equation (2) yields:

(4) $$L = -\frac{b_1' P_w W}{P_1}$$

(5) $$C = -\frac{b_2' P_w W}{P_c}$$

(6) $$\log W = \frac{k + b_1' \log - \frac{P_w b_1'}{P_1} + b_2' \log - \frac{P_w b_2'}{P_c}}{1 - b_1' - b_2'}$$

The optimum combination of inputs can then be determined by substitution of factor prices in equations (4), (5), and (6). Further details on the methods and assumptions used in this portion of the study can be found in "A Method for Selecting Least-Cost Irrigation Distribution Systems," Moore, C.V., Journal of Farm Economics Vol. XLV, No. 5, December 1963, pp. 1238-42. The fitted equations for the 640-acre farms are: $W = 4.38589 - .1422L - .13281C$ for the light sandy soil and $W = 3.88429 - .087475L - .123727C$ for the heavy silty clay soil. Respective R^2 are .88 and .82.

TABLE 4

Average Annual Capital Requirements Per Acre for Ten Water Distribution Systems on Two Soil Types for Four Sizes of Farm, Fresno County, California

	Sandy Loam Soil										
System numbers	1	2	3	4	5	6	7	8		9	10
Type of system	All open ditches				Concrete pipe every 1/4 mile				All concrete pipe		
Lateral spacing	1/4 mile		1/8 mile		1/4 mile		1/8 mile		1/4 mile	1/8 mile	
	Without return	With return	Without return	With return	Without return	With return	Without return	With return		Without return	With return
	dollars										
80-acre farm	0.86	4.87	1.52	9.20	3.51	7.49	4.16	11.84	a/ a/	6.55	15.29
160-acre farm	0.77	4.02	1.47	6.47	3.17	6.42	3.93	8.91		6.28	11.24
320-acre farm	0.72	3.61	1.42	6.39	3.07	5.91	3.73	8.66		5.81	10.69
640-acre farm	0.72	3.50	1.42	5.87	1.99	4.72	2.66	7.10		4.97	9.32

	Silty Clay Soil										
System numbers	1	2	3	4	5	6	7	8		9	10
Type of system	All open ditches				Concrete pipe every 1/2 mile				All concrete pipe		
Lateral spacing	1/2 mile		1/4 mile		1/2 mile		1/4 mile		1/2 mile	1/4 mile	
	Without return	With return	Without return	With return	Without return	With return	Without return	With return		Without return	With return
	dollars										
80-acre farm	0.32	4.49	0.81	6.68	1.75	5.66	2.24	7.98	a/ a/	4.04	9.86
160-acre farm	0.31	2.69	0.75	3.92	1.75	4.08	2.20	5.37		3.71	6.84
320-acre farm	0.31	2.69	0.75	2.98	1.73	4.08	2.20	4.40		3.53	5.70
640-acre farm	0.31	2.65	0.75	2.98	1.66	3.92	2.12	4.40		3.53	5.70

a/ Can be the same as systems five and six depending on number and location of wells on the farm.

NOTE: Average annual capital requirements are defined as the annual depreciation, taxes, and repair costs for each system.

Empirical Results of Least-Cost Irrigation Analysis

Farms of four different acreages were budgeted in this portion of the analysis -- 80, 160, 320, and 640 acres. As a result of the interviews of farmers, it was assumed that no technical economies existed in the use of irrigation labor and water inputs with respect to acres in the farm. No discernible differences could be found in water and irrigation labor use with respect to farm size. Table 4 summarizes the average annual capital per acre for the four farms by soil type.

Because of the "lumpiness" of a sump pump and return lines, the greatest cost savings per acre occur when larger areas are served by a single sump. This is indicated in Table 4 by the decrease in average annual capital requirement figures for systems containing return water structures.

The variable cost of pumping water (power plus repairs and maintenance) is quite different for the two soil type areas in this study. The variable cost (or price) of the water input is much higher in the area west of the Fresno Slough (about $10.60 per acre-foot) which contains the heavy soil than the lighter soils east of the Slough (about $1.50 per acre-foot). There is also some variation within subareas due to differences in elevation and pumping lift.

In Figures 3A, 3B, and 3C (80-acre and 640-acre sandy soil and 640-acre heavy soil farms), three dimensional charts are shown with an axis for each input -- water, labor, and capital. The elevated curves in the charts are the least-cost combinations of the three resources in the three dimensional space. The labor and capital costs for each of the ten budgeted irrigation systems are indicated on the "floor" of the charts.[1]

Chart A in Figure 3, for example, shows the effects of three wage rates and five water prices (variable cost) on the least-cost irrigation distribution system for an 80-acre farm with a sandy loam soil. The circled dots on the "floor" of the chart are the budgeted least-cost labor and capital combinations for the ten different distribution systems. Each of the curves connecting the pegs in the chart indicates the change in the least-cost combination as the price of water is increased from $5 to $10, $15, and $20 per acre-foot. Curve A holds the wage rate and interest rate constant at $0.50 per hour and six percent, respectively, as the price of water is varied. For curve B, the wage rate is set at $1.00 per hour and

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[1] Actual observations show only the labor and capital requirements. Water is omitted for ease of presentation.

FIGURE 3A

Least-Cost Irrigation Distribution Systems,
80-Acre Farm, Sandy Soil

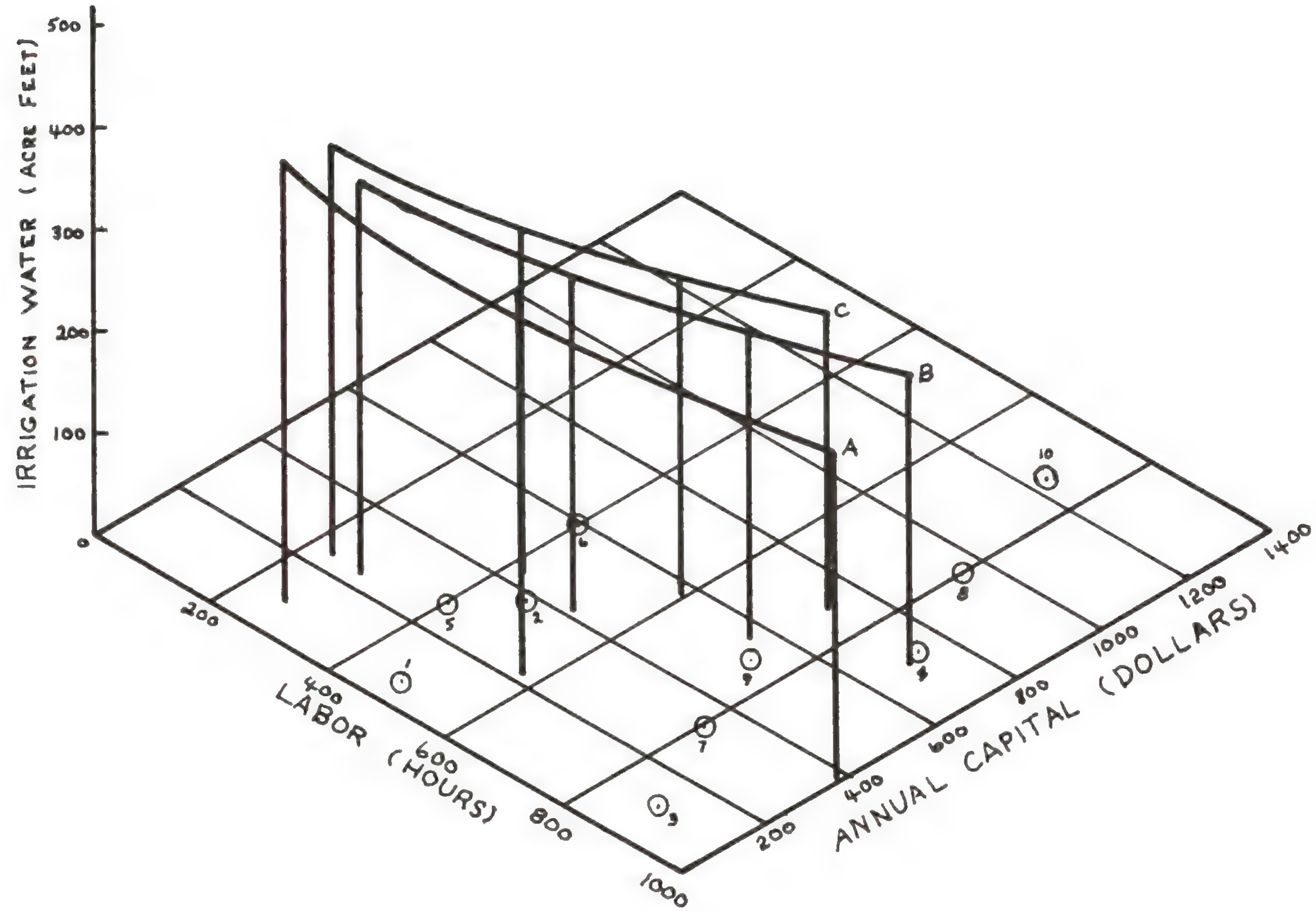


FIGURE 3B

Least-Cost Irrigation Distribution Systems, 640-Acre Farm, Sandy Soil

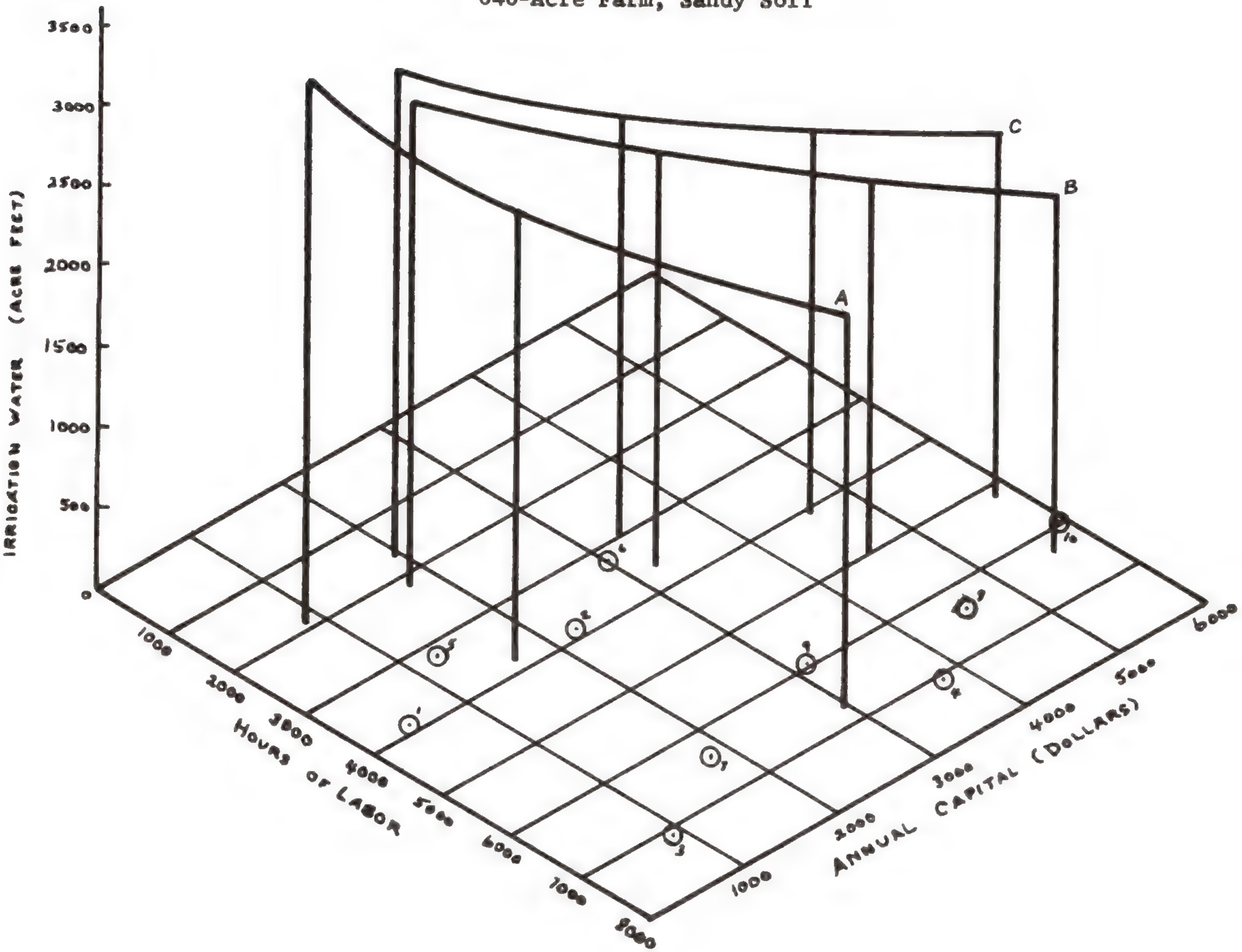
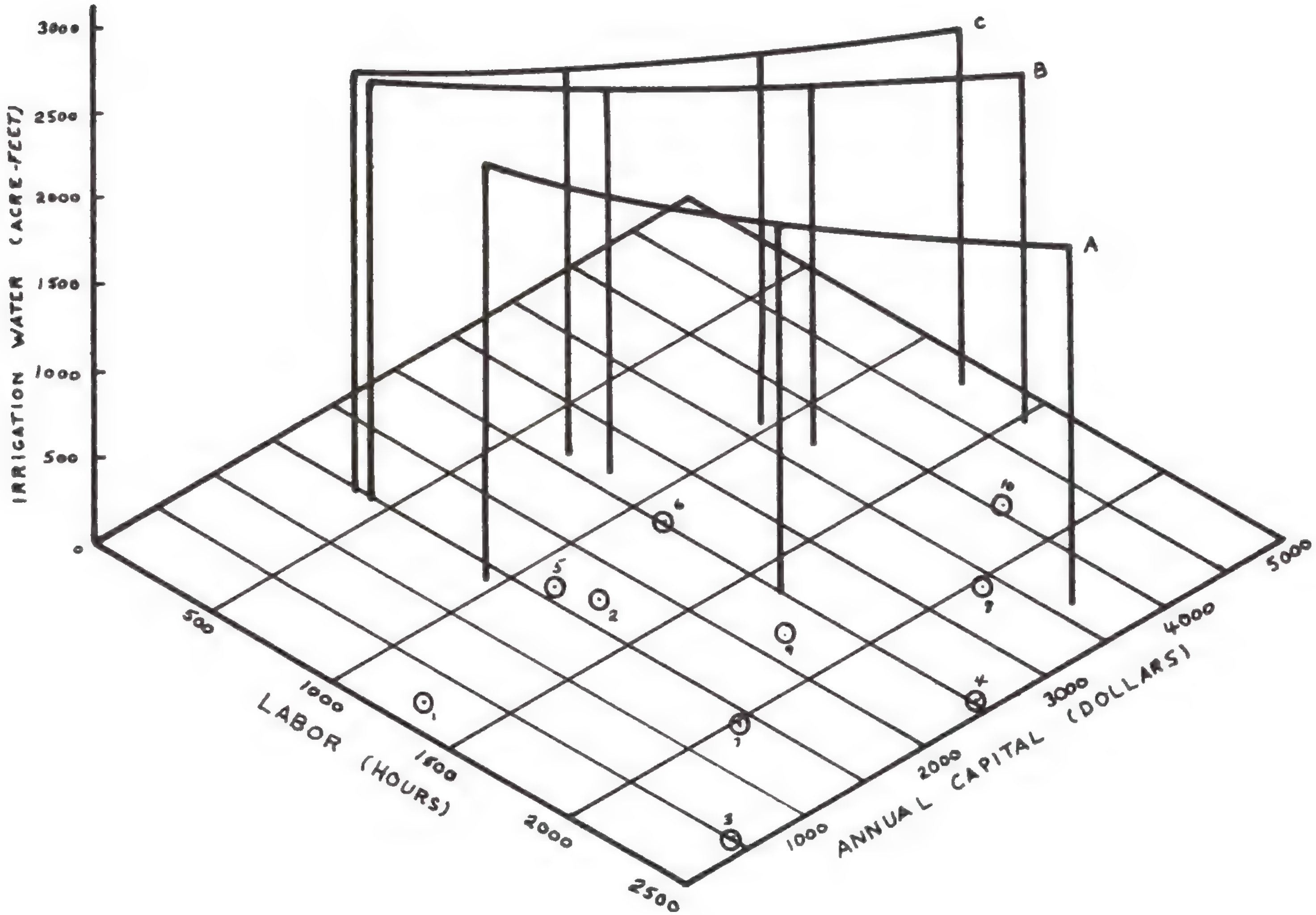


FIGURE 3C

Least-Cost Irrigation Distribution Systems, 640-Acre Farm, Heavy Soil



the interest rate is held constant at six percent. For curve C, the wage rate is set at $1.25 per hour and the interest rate is six percent on the capital invested in the irrigation distribution system.

When the analysis indicates an optimum combination of capital, labor, and water which does not fall exactly on one of the budgeted observations (circled dots), the least-cost distribution system would be the one nearest to the computed combination of inputs.

The least-cost combination is sensitive to changes in the wage rate. An increase in wages would cause a substitution of the less "dear" factors (water and capital) for the labor input. In Figure 3, the spread between the three traces, A using a wage of $0.50 per hour, B using $1.00 per hour, and C using $1.25 per hour, gives some indication of this effect.

The optimum distribution system changes with acres in the farms. Comparing the small with the large farm (light soil) as shown in Figure 3, the water cost and wage rate must be somewhat higher to justify investments in concrete pipeline and return water systems on the 80-acre farm than on a 640-acre farm. This is a result of the economies associated with farm size, especially the capital input as indicated in Table 4. This analysis indicates the same generalization can be made for farms situated on the heavier soils also.

The water prices assumed for the later analysis in this study are $10.60 per acre-foot for the heavy soil farms and $1.50 per acre-foot for the light soil farms. The seasonal labor wage rate, including social security and workman's compensation, is assumed to be $1.45 per hour. The interest rate used was six percent. Substituting these prices into the equations set forth in footnote one, page 15, indicates the least-cost distribution system to be number five for the sandy soil and number six for the heavy soil. That is, the analysis indicates that for the light soil farms the optimum distribution system is made up of concrete pipe mainline with a one-fourth mile spacing between laterals and no return water system. For the heavy soil farms, the optimum system contains concrete mainlines with the laterals spaced every one-half mile. This system contains a return water unit to recirculate tail water. A certain system is optimum for farms of different acreages within a soil type, although the per acre costs vary, because a system cannot be adjusted precisely to moderate differences in irrigated acreage.

COTTON ALLOTMENTS AND LAND COST IN RELATION TO FARM SIZE

An analysis of ASCS records for Fresno County indicates that cotton allotments are a smaller percentage of crop land as size of farm increases. A one percent sample was taken of ASCS records for farms located in the study area portion of the county. These were grouped by farm size as shown in Table 5. Crop land, as used in classifying these farms, does not include acreage in trees and vines. Therefore, a farm may have 100 percent of the crop land as an allotment. This condition occurred only in the smallest farm size.

TABLE 5

Cotton Allotment as Percentage of Total Open Crop Land, by Size Groups, Western Fresno County, California, 1963

Item	Crop land acres						
	0-40	41-120	121-240	241-480	481-980	981-1,920	Greater than 1,920
Number of farms	53	45	24	14	12	4	40[a]
Percentage of crop land in cotton allotment	52	35	31	23	24	26	15

[a] Five percent sample in largest size group due to the small number of farms in this size group.

Source: Fresno County ASCS records.

Because cotton is one of the most profitable crops, the value of cotton allotments (i.e., "the privilege of growing") is capitalized into the market price of land. To estimate the extent of this capitalization of cotton allotments in land values, data were gathered on cash rents paid for land with and without cotton allotments attached.[1] Data collected showed a mean cash rent payment of $25 per acre for open land with no allotment and $80 per acre for land with a cotton allotment.

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[1] An attempt was made earlier to collect data on sales and selling prices of land; however, there were so few "arms-length" transactions, especially in the area west of the Fresno Slough, that this approach was abandoned.

To estimate the value of the land with different percentages of allotments, landlords' net incomes were capitalized at both five and six percent. The results of this computation are shown in Figure 4. The slope of the curve for the capitalized value at six percent indicates an increase of $9.16 per acre in value for each one percent increase in cotton allotment. A change in the capitalization rate from six to five percent would change the slope of the value curve from $9.16 per acre to $11.00 per acre for each one percent change in cotton allotment. These data are used in a later section to determine interest on investment and taxes as a part of overhead costs.

COSTS OF FIXED PLANT AND OVERHEAD RESOURCES

Year-round labor supply is the primary measure of farm size in this study. It is assumed that the year-round labor must be paid for the full 12 months, even though it may be underemployed during certain periods of the year. Operator labor used in the direct operation of the farm is charged at the same rate as tractor drivers. The portion of the operator's labor spent in supervision and management is charged at the higher rate paid to foremen. Table 6 indicates the annual fixed cost charged to the year-round labor supply. See Appendix Table 4 for a detailed breakdown of wages and perquisites used in this study.

TABLE 6

Annual Fixed Labor Costs by Farm Size

Item	1-man farm	2-man farm	4-man farm	8-man farm
	dollars			
Direct labor	4,380	8,760	17,520	35,040
Supervision	720	1,440	2,880	5,760
TOTAL	5,100	10,200	20,400	40,800

Irrigation pumps contribute an important part of costs, especially in the western part of the study area. In the heavy soils area west of the Fresno Slough, the average annual ownership costs for a typical pump and well is about $5,900.[1] The usual situation is to have one of these wells per section of land.

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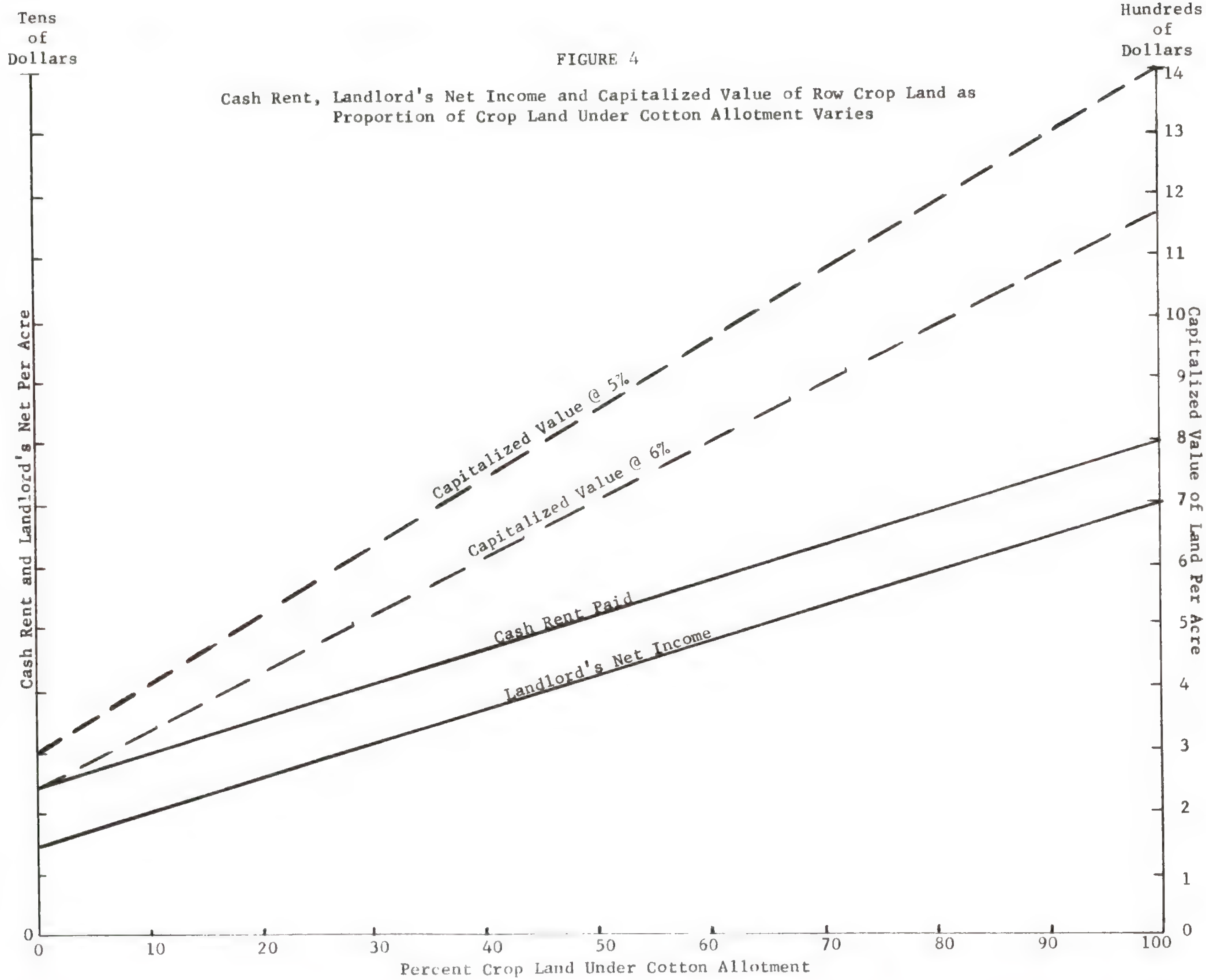
[1] Moore and Hedges, op. cit., p. 30.

FIGURE 4

Cash Rent, Landlord's Net Income and Capitalized Value of Row Crop Land as Proportion of Crop Land Under Cotton Allotment Varies



In this study, we have assumed that a farm would have at least one well even though there may be fewer than 640 acres in the farm. The optimum number of wells for heavy soil farms, larger than 640 acres, was determined in the linear programming analysis.

Wells are not nearly as deep and average annual ownership costs are correspondingly lower east of the Fresno Slough. For this light soil area, the average annual ownership cost per well is estimated to be $711. The number of wells per section of land is greater in this area. Based on survey data, we have assumed that farmers will maintain a pumping capacity of about 18 g.p.m. per acre of crop land. This means that one well will service about 80 acres.

Land ownership costs are another important factor contributing to total costs. Based on the data presented earlier on the relationship between cash rents and cotton allotments, the information presented in Table 7 indicates the annual ownership costs per acre, assumed for this study, based on the capitalized prices developed in the previous section. Total annual costs per acre cover taxes and interest on investment.

TABLE 7

Assumed Average Annual Land Ownership Costs Per Acre, and
Cotton Allotment as Percentage of Crop Land,
Four Farm Sizes [a]

Item	Unit	1-man farm	2-man farm	4-man farm	8-man farm
Percent cotton allotment	percent	30	25	23	15
Total annual cost per acre	dollars	36.49	33.36	32.10	27.10

[a] Although Figure 4 indicates costs vary with percentage of crop land in cotton allotment, constant allotments and costs are assumed for each farm size to simplify calculations.

Machinery costs vary with the hours of annual use. Armstrong and Faris[1] have analyzed the results of changing annual use and performance rates on machinery costs under San Joaquin Valley conditions. They have made careful estimates of the effect of hours of annual use on the expected life and, therefore, the annual depreciation charge and repair costs for a large group of machinery and equipment combinations. Machinery costs and rates of accomplishment used in this study are based upon the Armstrong and Faris data.

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[1] Armstrong, David L., and J. Edwin Faris, Farm Machinery: Costs, Performance Rates and Combinations, Southern San Joaquin Valley, California, Berkeley: University of California, Agricultural Experiment Station, Giannini Foundation Research Report No. 273, March 1964, 73 pp.

Other overhead items such as accounting, organization, and office supplies are charged at a constant $0.50 per acre based on our survey data.

LEAST-COST COMBINATIONS

Least-cost combinations of land, labor, and machinery were determined for at least five levels of gross farm income for each farm size (year-round labor supply), using linear programming. Heavy tillage equipment (crawler tractors, plows, and disks) were specified in the programming model for each farm size under study. The size and capacity of these tillage units were taken from Faris and Armstrong[1/] under the assumption that draft requirements were 50 percent greater for the heavy soil over the light soil. This resulted in crawler tractors one size larger on the heavy soil farm units than on the light soil units for the same number of tilled acres. Specification of the heavy tillage equipment allows more concentration on the cultivating and harvest machinery combinations that will minimize costs.

Harvest and cultivating equipment combinations were evaluated by comparing the average total costs for producing a specified gross income. For example, for the one-man light soil unit, six possible combinations of machinery were considered. First, all custom harvest with one wheel tractor for cultivation; second, a one-row cotton picker with the remainder of the crops being contract-harvested. The third possible combination was a one-row picker plus a 12-foot swather and pull-type baler, with the small grains being custom harvested. The fourth combination, substituted a self-propelled baler for the pull-type in combination three. Combinations five and six allowed the ownership of a self-propelled combine in conjunction with either a pull-type or self-propelled baler. Additional combinations of larger capacity machines were studied on the larger farms.

[1/] Armstrong and Faris, op. cit., p. 39.

The procedure of calculating and comparing average total cost not only helps in evaluating an individual machine and the cost per unit, as the machine is used at different capacities, but also takes into account the returns from alternative uses of labor released by labor-saving equipment. In other words, the purpose here is to evaluate a piece of equipment by noting its impact on the overall farming operation, not as an isolated item operating independently. Figures 5 and 6 show curves connecting the minimum cost machinery combinations for each of the farms considered.

Light Soil Farms

For the smallest light soil farm unit studied (one-man), the combination of a one-row cotton picker with a single wheel tractor for cultivating provided the minimum cost per dollar of gross income for all acreages up to about 160 acres, or $35,000 gross income. For this combination, all small grains would be custom-harvested and alfalfa hay would be mowed, raked, baled, and roadsided by contract operators. For a slightly larger farm, 160 to 200 acres of land, the addition of a 12-foot swather and pull-type three-wire baler becomes feasible along with the one-row cotton picker. This additional acreage and equipment involves hiring some temporary seasonal help during the peak summer months of June and July. With the fixed labor supply for one man, any additional increases in acreage and/or output, requires utilization of custom operators for all harvesting, including cotton picking. The profitability of these additional acres more than offsets, in this case, the savings of greater utilization of machinery capacity. The minimum point on the one-man cost curve is $0.84 per dollar of gross income at a gross revenue of $45,000 (see Figure 5).

An analysis of machinery and equipment of the two-man light soil unit considered nine different machinery combinations over a range of gross income from $45,000 to $85,000. These nine possible combinations included consideration of custom harvesting, one- and two-row cotton pickers, two types of balers, field hay waferer, and 12-foot combine.

Owning a one-row cotton picker in conjunction with a pull-type baler and 12-foot swather is the least-cost line of equipment up to about 275 acres of land.

FIGURE 5

Short-Run Average Cost Curves
By Farm Size, Light Soils, Fresno County

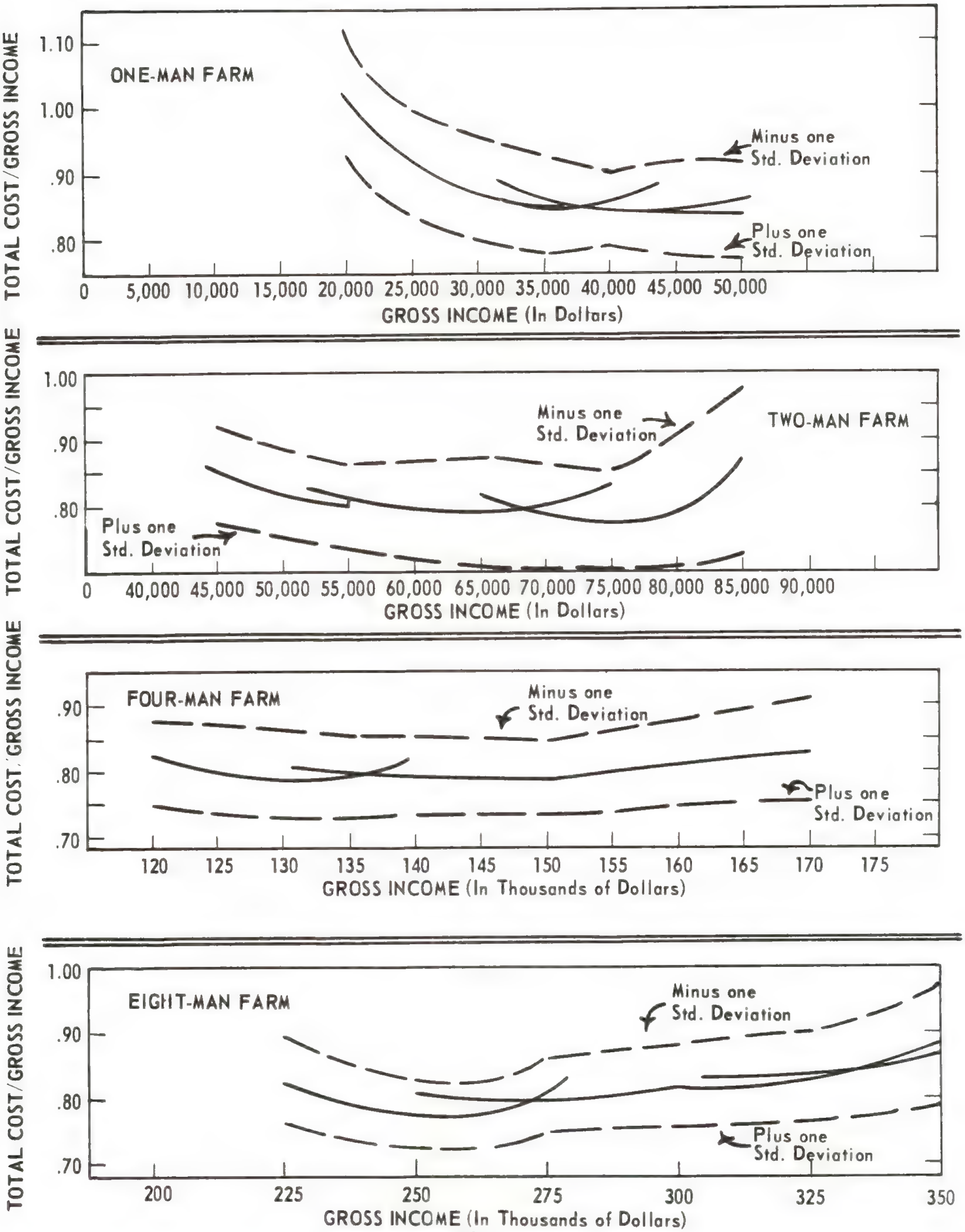
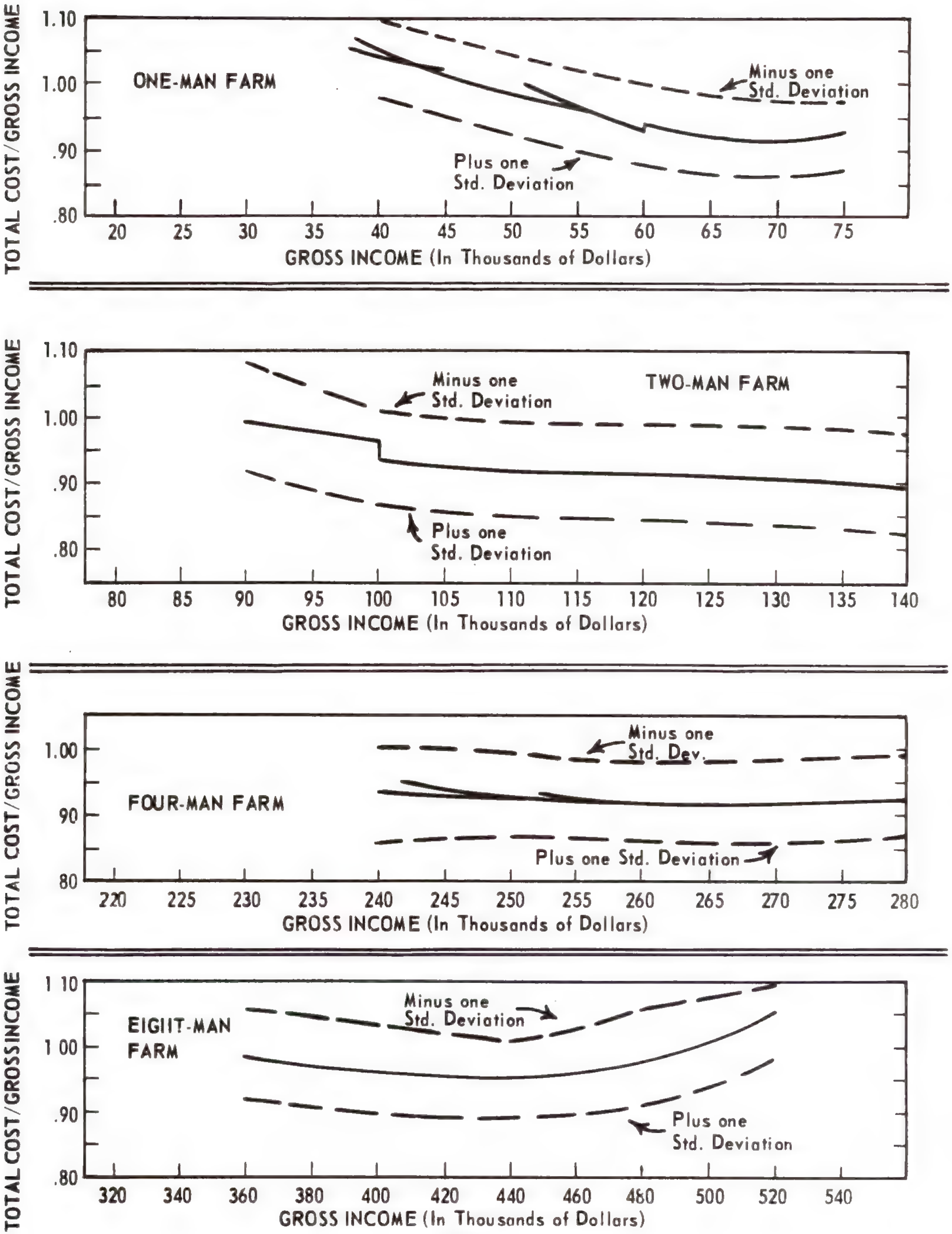


FIGURE 6

Short-Run Average Cost Curves
By Farm Size, Heavy Soils, Fresno County



Cotton-alfalfa hay farms over 275 acres can minimize costs by substituting a two-row cotton picker for the one-row picker. This combination had a cost per dollar of gross income of $0.84 at $65,000 or about 350 acres of land.

A greater gross income per acre can be achieved by use of a field hay waferer due to the $5 per ton premium for wafers.[1] Minimum costs were obtained for a gross income of $75,000 on 300 acres of land with a field waferer, 12-foot swather, two-row cotton picker, and two wheel tractors for cultivation and light land preparation. This combination of equipment utilized the entire year-round labor supply plus a small amount of seasonal labor; at its minimum point, the cost per dollar of gross income was $0.83.

Four full-time men operating a field hay waferer and two-row cotton pickers obtain the least-cost per unit of output for a cropping program of cotton-alfalfa hay and a minor amount of small grains. The latter are best harvested by a custom operator. This least-cost combination holds over a wide range of acreage -- from about 640 acres to slightly more than 1,000 acres. The combination of a self-propelled baler plus swather and two-row pickers is optimum for a small acreage -- less than a section of land on the four-man light soil farm. This cost curve is very flat but attains a minimum of $0.79 at a gross income of $150,000.

For an eight-man farm operating on the light soils, costs are minimized when the operating unit is about 1,600 acres. The least-cost machinery operation includes a self-propelled baler and swather plus two two-row cotton pickers. Additional output can be obtained with increasing costs per unit by substituting a field hay waferer and its accompanying equipment for the baler. Costs continue to decrease with the minimum of $0.77 being achieved at $250,000 gross income.

Heavy Soil Farms

Machinery combinations that minimize costs on the heavy soils contain a greater investment in crawler tractors due to the higher draft requirements of these soils. Harvest and cultivating equipment combinations considered for the one-man heavy soil unit include one- and two-row cotton pickers, sugar beet diggers, and self-propelled combines as well as the alternative of hiring custom operators.

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[1] A $5 per ton differential above the selling price of baled hay was assumed for wafered hay based on: "Economics of Hay Wafering," Dobie, J.B., R.G. Curley, and P.S. Parsons, Agricultural Engineering, Vol. 45, No. 2, February 1964, pp. 74-77.

Costs per dollar of gross income decrease rapidly for the one-man farm as output increases. To make labor available to produce this additional output, contract harvesting for all crops becomes necessary. Contract harvesting releases labor in the critical time period of October, November, and December for tillage and seedbed preparation for the next year's crop. Costs per dollar of gross income decrease rapidly, reaching a minimum of $0.91 at a $70,000 gross income (see Figure 6).

With the addition of the second full-time man on the heavy soil farm, acreage can be expanded sufficiently to make ownership of a one-row cotton picker feasible up to about 90 acres of cotton. With the aid of one seasonal laborer in the fall, the two-man operation can cover about 640 acres of farm land although about one-third of this land is fallow, due to the limited water supply. Costs are minimized with this labor supply acreage by utilizing a two-row cotton picker and having the small grains custom harvested. The minimum point of $0.89 is achieved here at a gross income of $140,000.

Doubling the labor supply to form a four-man farm on the heavy soil allows fall-harvested sugar beets to come into the cropping program under contract harvest. The labor supply of the four-man farm allows a large enough acreage of small grains to make feasible the ownership of a 12-foot self-propelled combine as well as two two-row cotton pickers. This cost curve is quite flat, reaching a low of $0.86 at $270,000 gross income.

The eight-man heavy soil farm becomes a multiple of the four-man farm in terms of least-cost machinery for harvesting. Harvest costs are minimized by utilizing two-row cotton pickers, two self-propelled combines, and having the sugar beets dug under contract. Costs per unit of output are lowest for this combination of labor and machinery when they are operating a farm in the 2,500- to 3,200-acre range. The minimum point on this cost curve is $0.90 at a gross income of $440,000. The reason why the four-man farm has higher minimum costs than the eight-man farm will be explained later in the discussion of the long-run cost curves.

GROSS INCOME VARIABILITY

The variability of gross income from a specified combination of production resources in the short run, as calculated in this study, gives some indication of the very wide ranges within which cost curves can be expected to fluctuate.

Tables 8 and 9 indicate one standard deviation for gross income and the coefficient of relative variability[1] for all farm sizes on both soils. Assuming a normal (bell-shaped) distribution of gross income,[2] two-thirds of the time, farmers would expect to receive a gross income somewhere within a range of plus or minus one standard deviation away from the calculated gross income. These fluctuations are due to random occurrences as reflected in prices received and yields obtained.

Standard deviations of incomes cannot be compared directly. Therefore, we have computed the coefficient of relative variability whereby income variability within and among farm sizes and soils can be compared.

Gross income variability for the light soils is relatively large but fairly stable. The cropping program contains primarily cotton, either skip row or solid plant, and alfalfa hay. Variability increases when the fixed resources are pushed to their capacity and small grains are added to cropping plans.

Relative variability of gross income on heavy soil farms is generally lower than on the lighter soils. The lower variability of gross income on the heavy soils is due to the small price and yield variances found for cotton, alfalfa seed, and sugar beets -- the three predominant crops in the heavy soil cropping plans. Whereas, the light soil cropping plans are dominated by cotton and alfalfa hay, the latter having a large gross income variance.

NET FARM INCOME VARIABILITY

Net incomes associated with the least-cost combinations and optimum cropping plans which were calculated using linear programming are shown in Figures 7 and 8.

Net income variability is composed of the random elements affecting price and yield as well as production costs. Because of the added component of cost variability, the relative net income variabilities are larger than for gross

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[1] Cost variability was determined by applying the variate difference method to a deflated time series of budgeted production inputs. Coefficient of Relative Variability = Standard Deviation (computed by variate difference method) divided by calculated income using 1967 projected prices.

[2] It is assumed here that no variability exists in the total cost element and the average cost ratio is a constant divided by a variate, not a ratio of two variates.

TABLE 8

Standard Deviation and Relative Variability of Calculated Gross Income by Farm Size, Light Soil Farms, Fresno County, California

Item	Unit	One-man farm calculated gross income						
		50,000	45,000	40,000	35,000	30,000	25,000	20,000
Standard deviation	dol.	4,400	3,996	2,702	3,108	2,664	2,220	1,777
Relative variability	pct.	8.8	8.8	6.7	8.8	8.8	8.8	8.8
		Two-man farm calculated gross income						
		85,000	75,000	65,000	55,000	45,000		
Standard deviation	dol.	8,897	6,001	5,458	4,318	3,533		
Relative variability	pct.	10.4	8.0	8.3	7.8	7.8		
		Four-man farm calculated gross income						
		170,000	160,000	150,000	140,000	130,000		
Standard deviation	dol.	15,839	12,542	11,255	10,272	10,526		
Relative variability	pct.	9.3	7.8	7.5	7.3	8.0		
		Eight-man farm calculated gross income						
		350,000	325,000	300,000	275,000	250,000	225,000	
Standard deviation	dol.	36,781	27,168	23,009	19,688	17,430	18,123	
Relative variability	pct.	10.5	8.3	7.6	7.1	7.0	8.0	

TABLE 9

Standard Deviation and Relative Variability of Calculated Gross Income by Farm Size, Heavy Soil Farms, Fresno County, California

Item	Unit	One-man farm calculated gross income					
		75,000	70,000	60,000	50,000	40,000	
Standard deviation	dol.	4,827	4,321	3,753	3,075	2,799	
Relative variability	pct.	6.4	6.2	6.2	6.1	7.0	
		Two-man farm calculated gross income					
		140,000	130,000	120,000	110,000	100,000	90,000
Standard deviation	dol.	11,534	10,318	9,206	8,235	7,772	7,234
Relative variability	pct.	8.2	7.9	7.7	7.4	7.8	8.0
		Four-man farm calculated gross income					
		280,000	270,000	260,000	250,000	240,000	
Standard deviation	dol.	19,031	18,442	18,523	17,073	19,536	
Relative variability	pct.	6.8	6.8	7.1	6.8	8.1	
		Eight-man farm calculated gross income					
		520,000	480,000	440,000	400,000	360,000	
Standard deviation	dol.	39,166	37,096	32,396	30,443	25,953	
Relative variability	pct.	7.5	7.7	7.4	7.6	7.2	

FIGURE 7

Net Farm Income, Light Soil Farms,
Fresno County

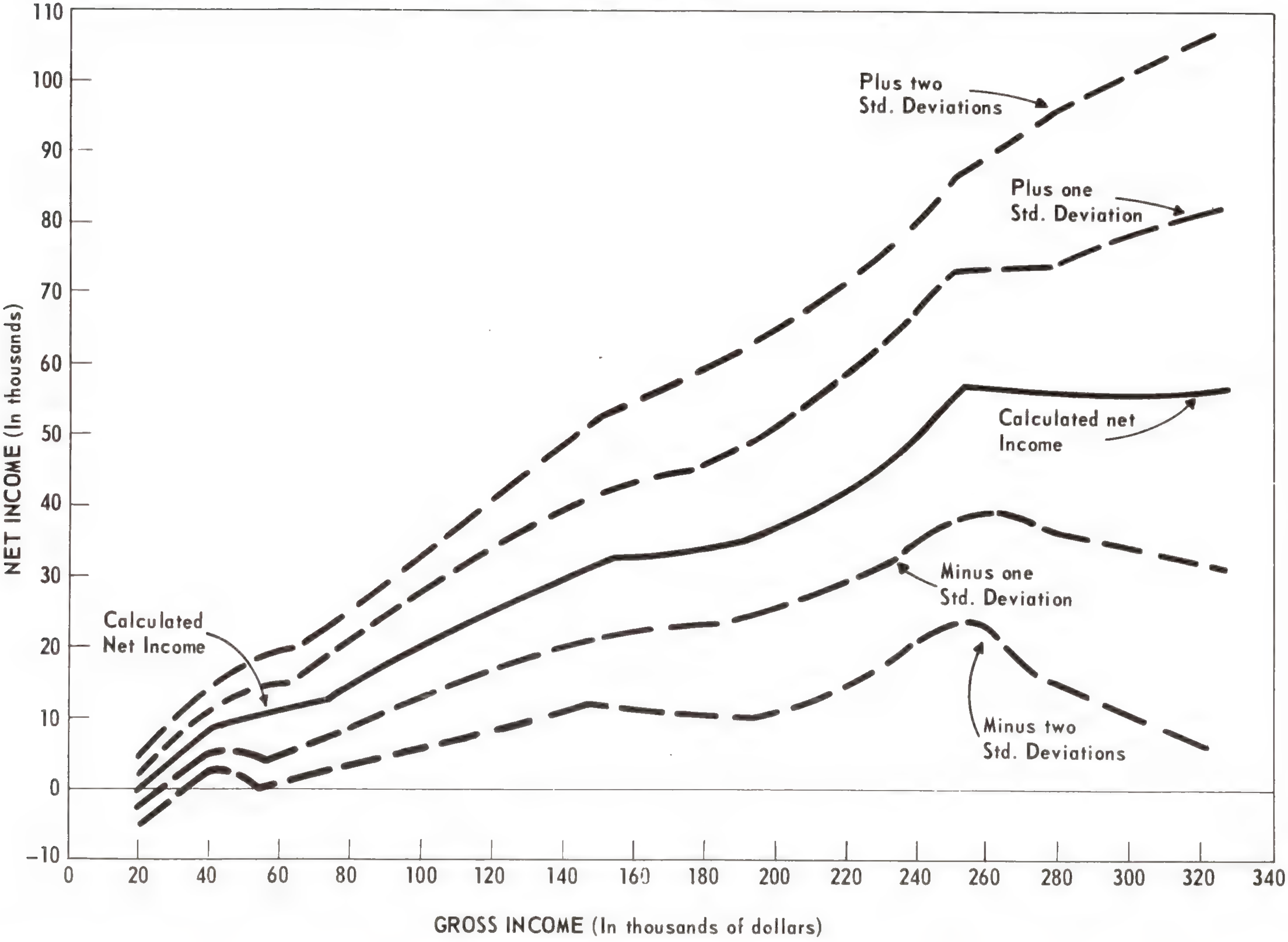
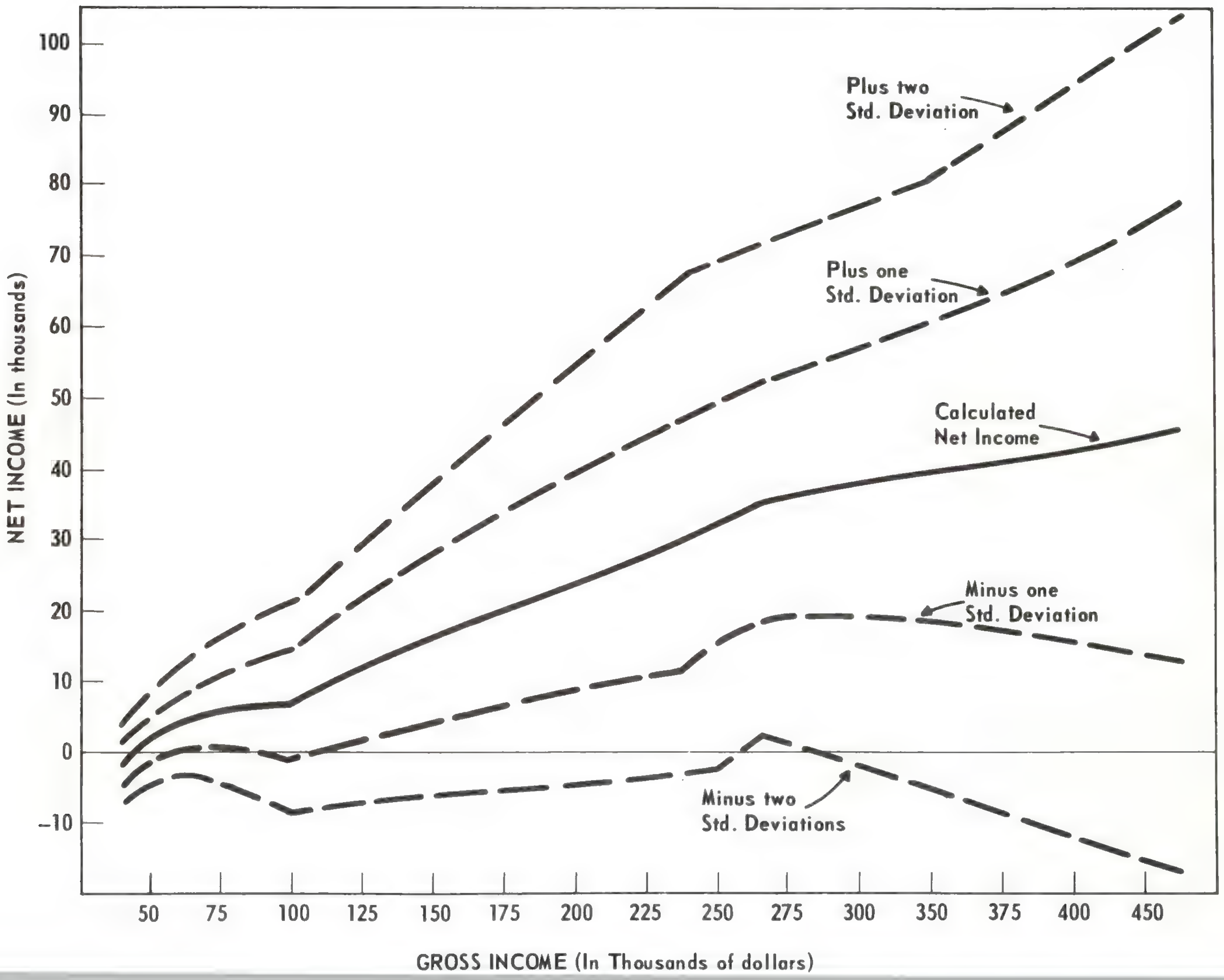


FIGURE 8

Net Farm Income, Heavy Soil Farms, Fresno County



income. Therefore, again assuming a normal distribution, the area encompassed by plus or minus one standard deviation about the calculated net income is quite large. This area indicates the region within which the calculated income can be expected to fall about two-thirds of the time. Since most expansions in size of operations and all debt repayment must come from net incomes, both the absolute and relative magnitude of this area must be taken into account.

For example, on the heavy soil farms at $250,000 gross income, the range encompassed by plus and minus one standard deviation away from the calculated net income is from $15,000 to $48,000, or $33,000. At $100,000 gross revenue, this range is from -$1,000 to +$14,000, or $15,000. The actual net income can be expected to fall within this range two-thirds of the time and outside (either higher or lower) the other one-third of the time. The cone-shaped area outlined by plus or minus one standard deviation indicates the absolute "risk"[1] involved in an expanded operation, especially one financed on a small equity. For example, the farm grossing $100,000 on the heavy soil cited above, could, if operating on 100 percent equity, weather several poor years where the net income was negative. On the other hand, if a large fixed debt repayment out of net income was necessary, two poor years in a row could put the farm owner in a difficult financial position. Several poor years in a row are quite possible even though, over a period of years, the annual incomes were expected to average out to the calculated one.

TECHNICAL ECONOMIES OF FARM SIZE

A smooth curve drawn tangent to (just touching) the series of short-run cost curves traces out the cost planning curve. The assumption underlying this curve is that all inputs are variable as the time span under consideration is lengthened and it therefore traces out the minimum cost of producing any output.[2] As discussed earlier, there are a very large number of "fixed plants"[3] that could be analyzed in studying the relevant range of output. In this study, only four "fixed plants" have been analyzed. Because of this small number of "fixed plants," we have necessarily had to draw the planning curve across the gaps between short-run curves.

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[1] In the sense used here, risk means likelihood of bankruptcy. Technically, risk is not related to equity.

[2] Including cotton allotment acreage as a restriction causes this analysis to fail to meet the requirement for a long-run cost curve. By definition, in the long run, all factors are variable. However, the curves presented here are realistic long-run planning curves as faced by present-day operators.

[3] The reader is reminded that in this study fixed plants are defined in terms of year-round regular labor supply.

The cost planning curves for the light and heavy soil farms are shown in Figures 9 and 10, respectively. Average total costs for the light soil farms decrease rapidly as output is increased and then tend to level out in the 240- to 300-acre farm range. Costs again start to decrease after this acreage when, for the first time, a field hay waferer becomes economically feasible. The cost planning curve flattens out when gross income reaches the $250,000 level for a farm in the 1,200- to 1,600-acre range. Substantially all of the cost reductions due to increases in farm size, however, have been achieved by the time gross income has reached $140,000 for a farm in the 600- to 800-acre range.

The band around the cost planning curve in Figure 9, for the light soil farms, was developed by dividing the calculated total costs by plus and minus one standard deviation of gross income about the calculated gross income. That is, the upper curve is found by dividing calculated total cost by minus one standard deviation away from calculated gross income and by the same method the lower curve is found by using plus one standard deviation. This figure measures the variability only of prices and yields and is smaller than the band around the net income curve shown earlier which included cost variability.

The acreage figures shown along the base line of the cost planning curve charts are not graduated because gross income per acre is not constant over the range of farm sizes studied. They were placed there to help orientate the reader and indicate only, in an approximate way, the farm size as measured in acres of land.

The shape of the heavy soil cost planning curve is strikingly different from the light soil farm in that it tends to turn up after a certain size is reached. For the heavy soil farms, the cost planning curve decreases rapidly as output is increased, especially up to about $150,000 gross income or about a section of land. This is due, in part, to the high investment required to drill an irrigation well in this area of the Valley. Average costs on the heavy soil farms continue to decrease up to about $275,000 gross income or a farm in the 1,200- to 1,400-acre size range. After this size farm has been reached, average total costs start to increase and continue to do so up to the limit of

FIGURE 9

Planning Curve
Cotton Farms, Light Soil, Fresno County

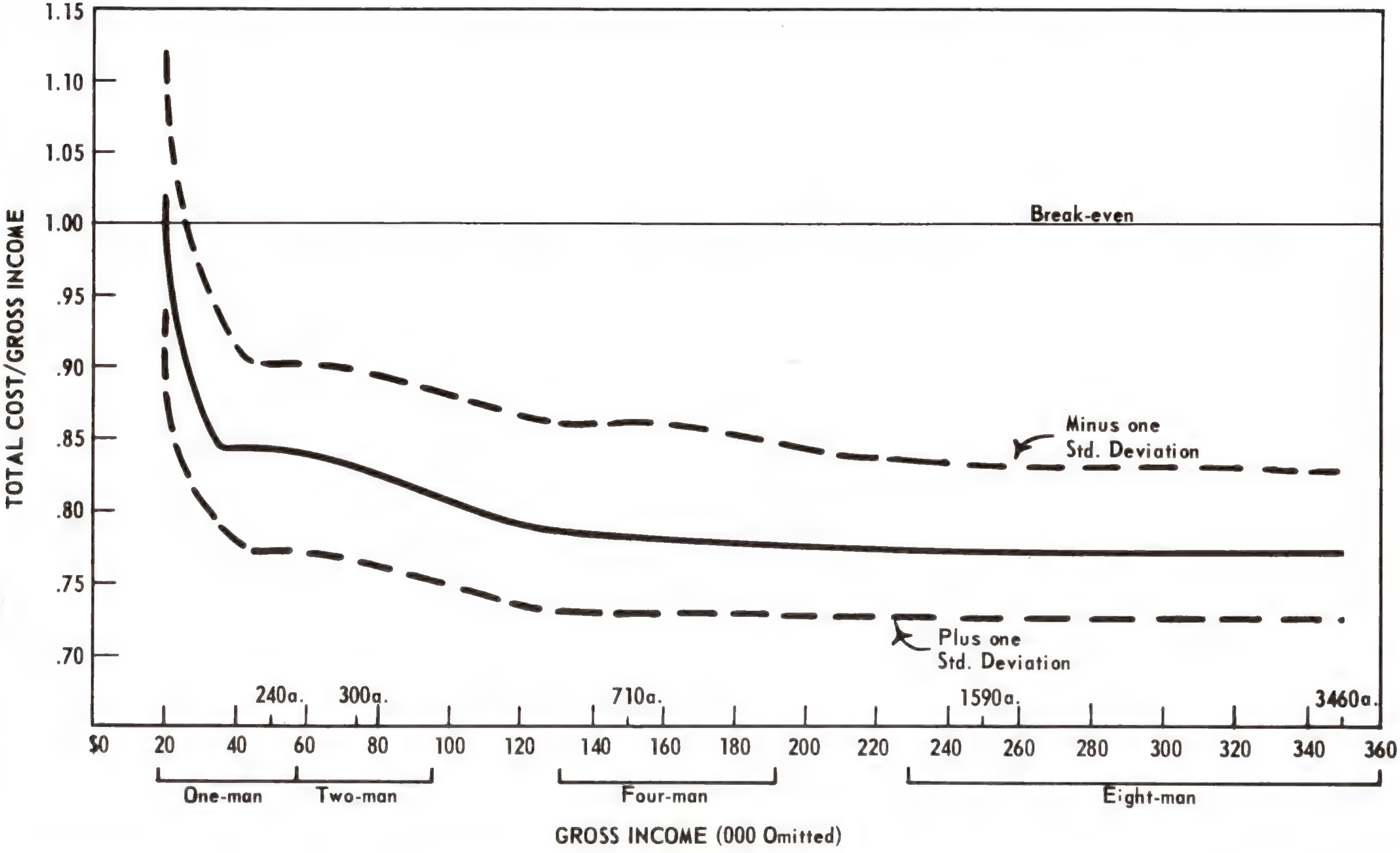
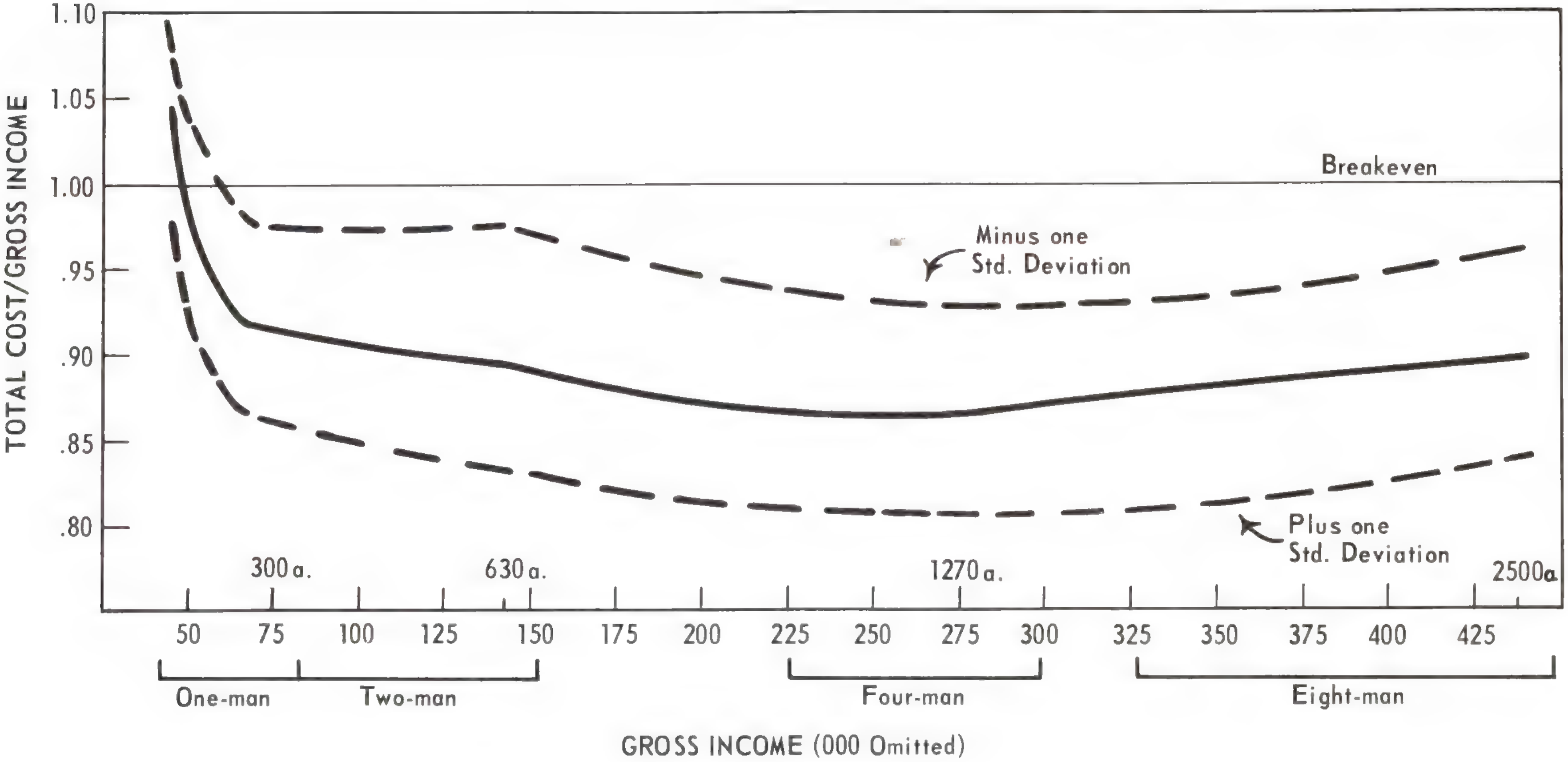


FIGURE 10

Planning Curve
Cotton Farms, Heavy Soil, Fresno County



the farm sizes presented in this report. The primary cause of this increase in costs, due to farm size, is the decrease in the percentage of farm land under cotton allotment as farm size increases. This condition is more critical to the heavy soil farms than the light soil farms. Heavy soil farms do not have an unrestricted profitable alternative crop to replace cotton, such as alfalfa hay, as do the light soil farms. Although the same percent cotton allotments were assumed for both soils as acres of farm land increased (see Table 6, page 23), cotton is replaced by low-value crops, such as safflower and barley or left fallow, when allotments are decreased on the heavy soils.

The plus and minus one standard deviation of gross income band is narrower around the heavy soil cost curve than that of the light soil. This reflects the lower relative variability of the heavy soil cropping programs as compared to the light soil crop plans.

The upturn in the heavy soil farm's cost planning curve does not mean that additional expansion beyond the minimum or least-cost point on the curve would be irrational. The farm would be profitable until the cost planning curve crosses above the break-even line. However, maximum net income will be obtained at an output somewhat less than this intersection with the break—even line.[1] As indicated by the net income curve in Figures 7 and 8, profit is maximized at about $425,000 gross income on a farm size of about 2,500 acres. If the long-run cost curve continues its upward trend, net income would decrease accordingly. The trend towards larger farms is due more to the expected additional income than to expected reduction in unit costs.

The high-cost water and heavy investment in tillage equipment puts the heavy soil farm units at a decided cost disadvantage as compared to the light soil units. The lack of profitable alternatives to cotton on farms on the heavy soil makes this part of the county particularly sensitive to lower cotton prices and acreage allotments.

SUMMARY

Soil textures, water supplies, and adopted crops have profound influences on slope and position of farm planning curves in Fresno County cotton farms.

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[1] Profit is at a maximum when long-run marginal cost equals average revenue (break-even line).

Least-cost irrigation distribution systems are affected by the cost of water, irrigation labor, and interest rates. Cost minimizing systems for light soil farms contained underground concrete pipe mainlines, quarter-mile lengths of run between laterals, but no return water systems. Heavy soil units needed the addition of return water systems primarily due to the much higher water costs in their area.

When the value of cotton acreage allotments becomes capitalized into land prices, the value of the land resource can vary widely due to the percentage of land in a farm which is cotton allotment. Our analysis indicated that capitalizing net landlords' cash rents at five percent gave a basic land value of $300 per acre for bare, level land and the value would increase $11 per acre for each one percent of the parcel that is cotton allotment.

Light soil farm units minimized costs per dollar of gross income by utilizing a one-row cotton picker, a pull-type baler plus a swather, and having any small grains custom harvested. This combination held for farms of less than 275 acres. When the labor supply for any farm size was pushed to its capacity, it became profitable to hire all harvesting done.

A field hay waferer became feasible for farms over 300 acres of land when used in conjunction with a two-row cotton picker. If a waferer was taken from consideration, a self-propelled baler became least-cost at about 640 acres of land.

Small heavy soil farm units can minimize costs by using all custom harvest operators rather than investing in large amounts of machinery. A one-row cotton picker becomes feasible with about 90 acres of land in cotton and a two-row picker at about 160 acres of cotton. Ownership of a self-propelled combine becomes feasible for farms of 1,200 acres of land or larger.

Confidence intervals were drawn about the short-run cost curves; these indicated that two-thirds of the time the A.T.C. would fall within plus or minus $0.05 to $0.08 of the expected cost.

The variability of net farm income was also analyzed. Confidence intervals drawn about the expected income curve indicated that for the smaller heavy soil units the possibility of negative income was rather high. On the other hand, light soil farm operators would have a stronger possibility of surviving adverse periods and capital accumulation could occur at a more rapid rate.

A planning curve drawn as an envelope to the series of short-run cost curves traced out the minimum cost of producing any output. Most of the cost economies were achieved on the light soil units by the time a gross income of $140,000 had been reached, which necessitates a land input of about 600 to 800 acres.

Cost savings continue to accrue to heavy soil unit operators as output is increased up to about $275,000 gross income or about 1,200 to 1,400 acres of land. Substantially all of the cost economies were achieved by the time gross income reached $150,000 or 640 acres of land.

APPENDIX TABLE 1

Assumed Prices Received by Farmers

Crop	Unit	Price
		dollars
Cotton lint	lb.	.338
Cotton scrappings	lb.	.30
Cotton seed	ton	50.50
Sugar beets	ton	12.20
Grain sorghum	cwt.	2.13
Barley	cwt.	2.29
Dry beans	cwt.	8.90
Alfalfa hay (baled)	ton	22.20
Alfalfa hay (wafered)	ton	27.20
Alfalfa seed	lb.	.45
Safflower	cwt.	3.75

Source: Based on projected U.S. Prices for 1967 in A Study Guide for a Cooperative Project in Farm Size, U.S. Department of Agriculture, Economic Research Service, Farm Production Economics Division, November 1963.

APPENDIX TABLE 2

Assumed Yields by Soil Type

Crop	Unit	Light soil		Heavy soil	
		Class I	Class II	Class I	Class II
Cotton (solid plant)[a]	bale	1.88	b/	2.15	c/
Cotton (skip row)[d]	bale	2.53	--	3.01	e/
Barley	cwt.	28.0	24.0	36.8	34.0
Grain sorghum	cwt.	48.0	40.0	47.0	42.0
Dry beans	cwt.	16.5	--	16.0	14.5
Alfalfa hay	ton	7.18	5.87	--	--
Alfalfa seed	lb.	--	--	500	450
Sugar beets	ton	--	--	20.0 (16% sugar)	16.0
Safflower	cwt.	--	--	33.0	28.0

a/ Includes five percent scrapped cotton from after final picking.

b/ Weighted average -- 40 percent Class I, 60 percent Class II.

c/ Weighted average -- 60 percent Class I, 40 percent Class II.

d/ Two rows planted, one row skipped.

e/ Yield per acre of allotment.

APPENDIX TABLE 3

Income Variability for Selected Crops, Fresno County

Item	Net income[a]							
	Dry beans	Milo	Alfalfa seed	Cotton[b]	Alfalfa hay	Sugar beets	Barley	Safflower
Standard deviation per acre	10.49	7.87	19.23	45.59	13.79	18.93	4.28	5.24
	Correlation between crops (rij)							
Dry beans	1	.55	.08	.36	.04	.27	.55	- .20
Milo		1	.19	.25	.13	.35	.19	.17
Alfalfa seed			1	- .02	--	- .13	.49	.21
Cotton b/				1	- .33	.13	.25	.47
Alfalfa hay (all)					1	--	.27	--
Sugar beets						1	.17	.32
Barley							1	.48
Safflower								1

Item	Gross income							
	Dry beans	Milo	Alfalfa seed	Cotton[b]	Alfalfa hay	Sugar beets	Barley	Safflower
Standard deviation per acre	8.39	9.15	21.19	46.56	15.31	19.47	4.65	5.21
	Correlation between crops (rij)							
Dry beans	1	.58	.15	.41	.06	.27	.40	- .16
Milo		1	.28	.26	.17	.36	- .04	.19
Alfalfa seed			1	.01	.50	- .04	.57	.23
Cotton				1	- .22	.12	.25	.39
Alfalfa hay (all)					1	- .16	.58	.09
Sugar beets						1	.21	.33
Barley							1	.62
Safflower								1

[a] Net income over production costs.

[b] In calculating total variance, gross acres planted were used as proportions.

APPENDIX TABLE 4

Assumed Labor Costs

	Costs per hour
General Labor	
Cash salary	$1.45
Perquisites	
(housing, utilities, etc.)	.33
Social security and workman's compensation	.11
Interest on operating capital	.07
TOTAL	$1.96
Supervisory Labor	
All supervisory labor was charged at a rate of $7,200 per year. It was assumed that for each worker, 10 percent of a supervisor's time would be withdrawn from the direct labor supply and charged at the higher rate, i.e., 40 percent of a supervisor's time would be charged at the higher rate on the four-man farm and 80 percent on the eight-man farm.	

APPENDIX TABLE 5

Farm Organization for Selected Sizes of Farm Along the Planning Curve, Light Soil Farms, Fresno County, California

Item	Size of farm in number of men in regular labor supply				
	Unit	1	2	4	8
Seasonal labor	hour	453	370	816	2,205
Irrigation wells	number	2	4	9	16
Tractor, crawler	number		1	1	2
Tractor, wheel	number	1	1	3	3
Cotton picker, one-row	number	1			
Cotton picker, two-row	number		1	1	1
Baler, pull-type	number		1		
Baler, self-propelled	number				1
Swather	number		1	1	2
Waferer	number			1	
Combine	number			1	
Cropping Program:					
Cotton (solid plant)	acre				
Cotton (skip row plant)	acre	40.4	82.1	163.2	238.6
Alfalfa hay	acre	106.8	171.6	352.6	705.2
Alfalfa seed	acre				238.3
Dry beans	acre			69.7	
Grain sorghum	acre				
Barley	acre				
Safflower	acre				
Sugar beets	acre				
Fallow	acre				193.7
Total land in farm	acre	193.0	349.3	709.7	1,590.3
Income:					
Gross income[a]	dollar	40,000	65,000	150,000	250,000
Net income	dollar	6,267	9,818	32,628	56,836
Total cost	dollar	33,733	55,182	117,371	193,164
Total cost/Gross income	percent	0.843	0.849	0.782	0.773

[a] Totals may not add due to rounding.

APPENDIX TABLE 6

Farm Organization for Selected Sizes of Farm Along the Planning Curve, Heavy Soil Farms, Fresno County, California

Item	Size of farm in number of men in regular labor supply				
	Unit	1	2	4	8
Seasonal labor	hour	202	672	556	971
Irrigation wells	number	1	2	3	6
Tractor, crawler	number	1	1	2	2
Tractor, wheel	number	1	2	3	5
Cotton picker, one-row	number				
Cotton picker, two-row	number		1	1	2
Baler, pull-type	number				
Baler, self-propelled	number				
Swather	number				
Waferer	number				
Combine	number		1	1	2
Cropping Program:					
Cotton (solid plant)	acre	76.1		49.5	441.3
Cotton (skip row plant)	acre		147.8	211.2	54.4
Alfalfa hay	acre				
Alfalfa seed	acre	86.5	226.3	355.7	442.5
Dry beans	acre	18.9	23.9	185.0	
Grain sorghum	acre				
Barley	acre		27.2	94.8	649.0
Safflower	acre	21.3			
Sugar beets	acre	50.6		63.9	277.3
Fallow	acre		100.0		1,021.3
Total land in farm	acre	270.0	628.9	1,133.6	3,304.9
Income:					
Gross income[a]	dollar	70,000	140,000	260,000	480,000
Net income	dollar	5,807	14,489	35,040	33,296
Total cost	dollar	64,192	125,510	224,959	446,704
Total cost/Gross income	percent	0.917	0.896	0.865	0.931

[a] Totals may not add due to rounding.